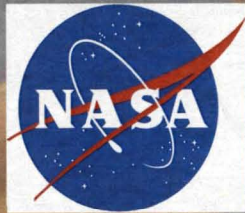


Kennedy Space Center

Image Analysis via Soft Computing: Prototype Applications at NASA KSC and Product Commercialization.



Kennedy Space Center



ASRC Aerospace Corp.

*Jesus A. Dominguez
Steve Klinko*

photo: NASVP at McCracken



Kennedy Space Center

Outline



- ***System Development.***
- ***Performance results compared with existing approaches.***
- ***NASA applications.***
- ***Commercialization.***



ASRC Aerospace Corp.

System Development

Kennedy Space Center



Soft Computing (SC):

differs from conventional (hard) computing in that, unlike hard computing, it is tolerant of imprecision, uncertainty, partial truth, and approximation.

provides flexible information processing to handle real life ambiguous situations and achieve tractability, robustness, low solution cost, and close resemblance of human decision making.



ASRC Aerospace Corp.



System Development

Kennedy Space Center



- *FRED (Fuzzy Reasoning Edge Detection):*

Image edge extraction technique developed at KSC (patent protected).

- *FRAT (Fuzzy Reasoning Adaptive Thresholding):*

Image binarization technique developed at KSC (patent protected).

- *Set of Image Enhancement Techniques:*

Techniques developed at KSC (one patent protected).

- *Visual/Pattern Recognition:*

Commercially available technique (NeuroShell) via Artificial Neural Network (ANN) and GA (Genetic Algorithm).



ASRC Aerospace Corp.

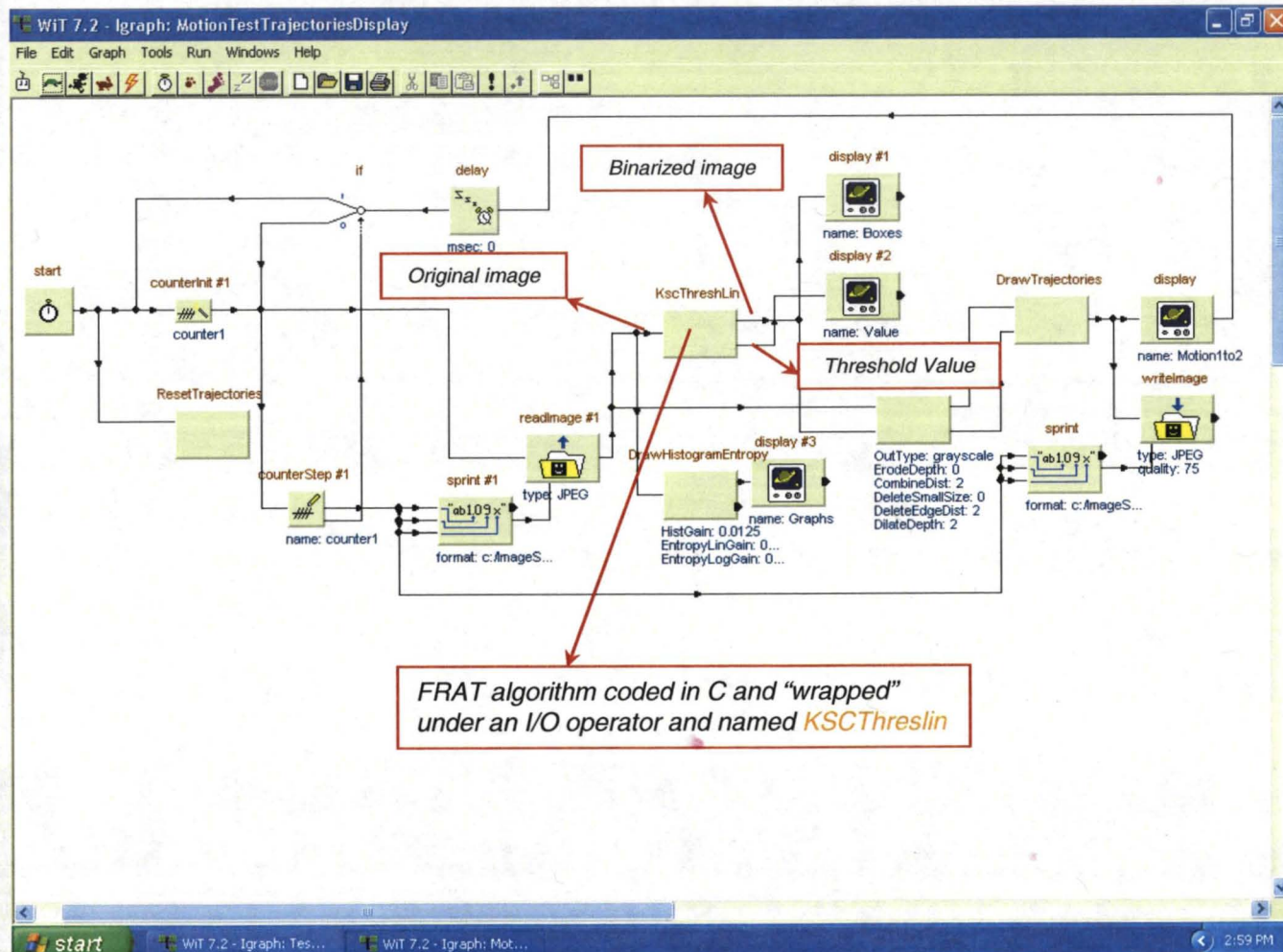


Software implementation (Cont).

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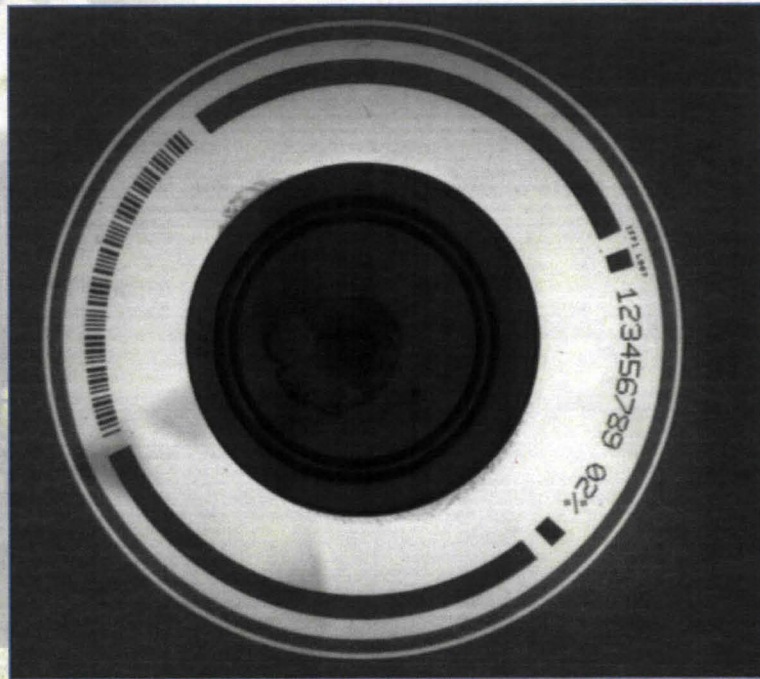


FRAT algorithm coded in C and “wrapped”
under an I/O operator and named **KSCThreslin**

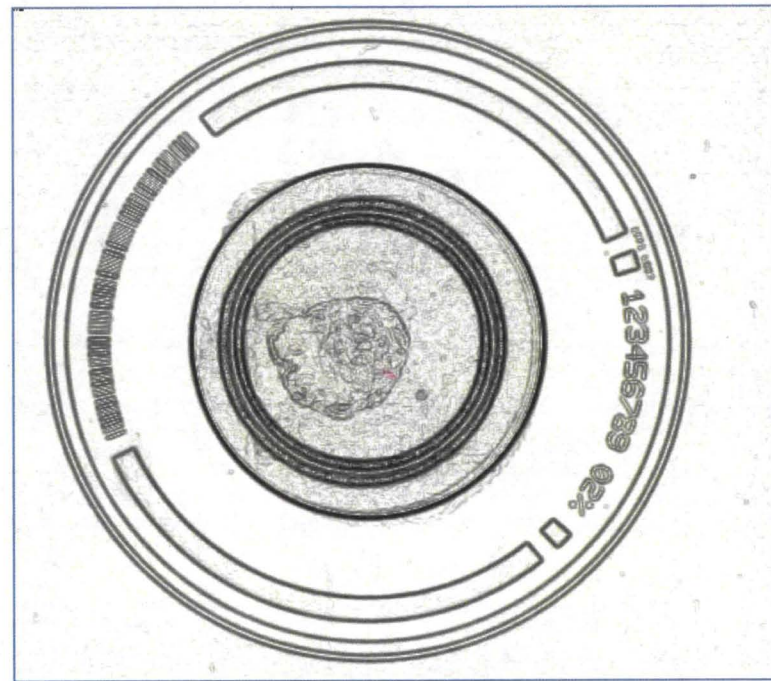


Performance results compared with existing approaches: FRED

Kennedy Space Center



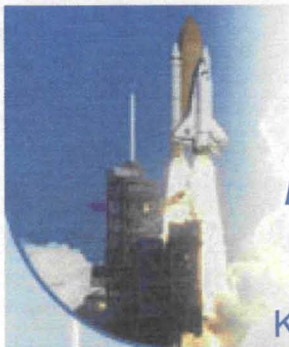
Original Image: CD containing a hard-to-see major scratch on the center



FRED: The major scratch is clearly shown as well as other minor ones

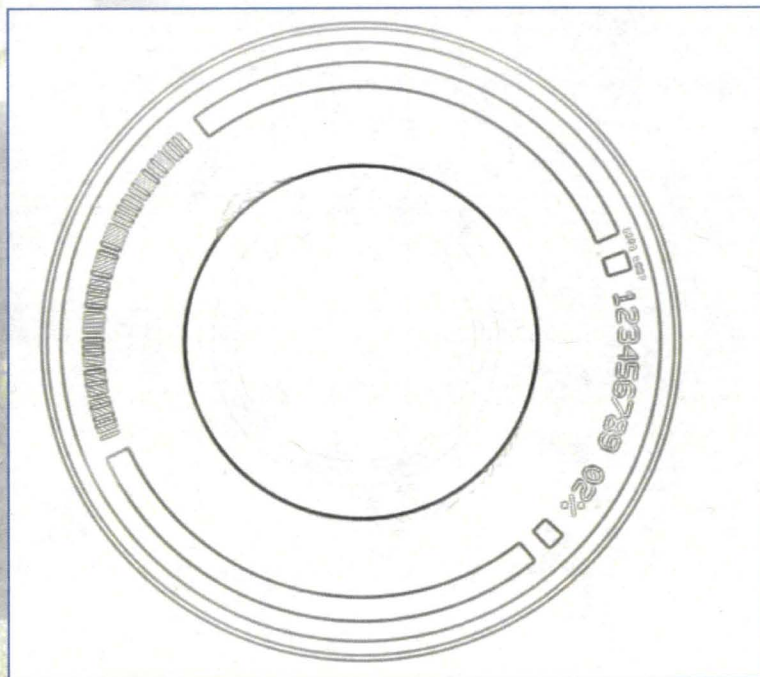


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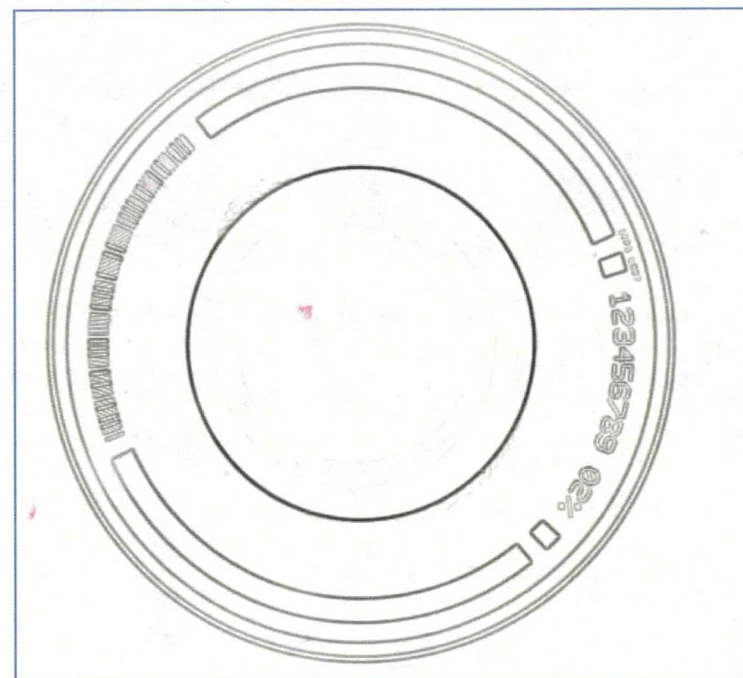


Performance results compared with existing approaches: FRED

Kennedy Space Center



Sobel Approach: less clear features, major scratch invisible



Prewit Approach: less clear feature, major scratch invisible

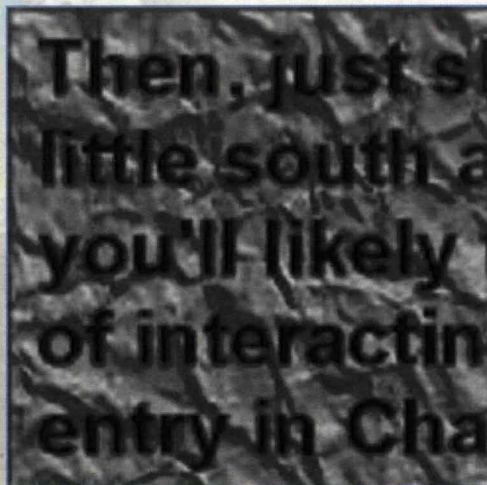


ASRC Aerospace Corp.

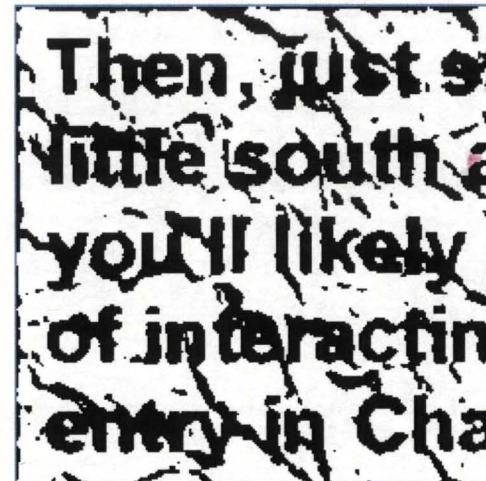


Kennedy Space Center

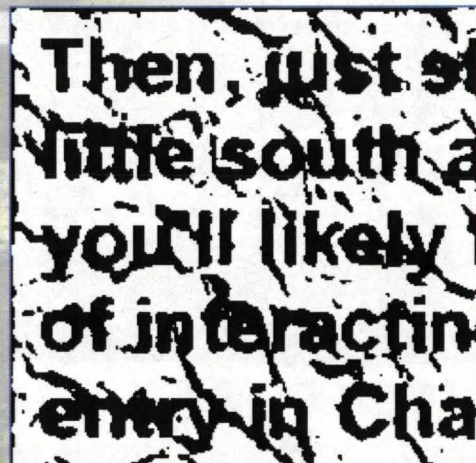
Performance results compared with existing approaches: FRAT



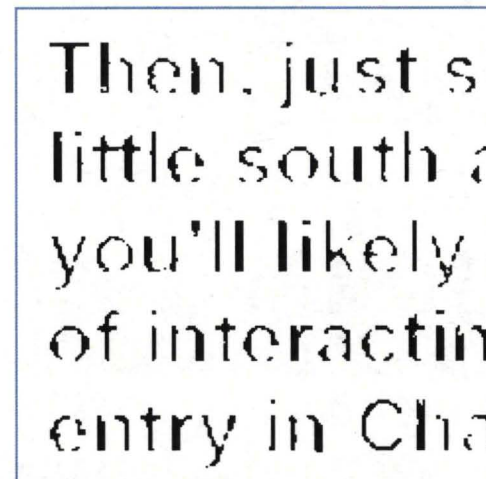
Original 8-bit Image
Size: 246×245



Otsu's Method
CPU time: 1.5 ms
Threshold: 88



Huang-Wang Method
CPU time: 10.8 ms
Threshold: 89



New Method
CPU time: 2.0 ms
Threshold: 8



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NASA Applications



ASRC Aerospace Corp.




- *Real-Time (RT) Anomaly Detection.*
- *Real-Time (RT) Moving Debris Detection.*
- *Columbia Investigation.*



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RT Anomaly Detection



- Image Preprocessing.
Enhancement
Segmentation (Binarization)  *FRAT*
- Classification and Learning Processes.
Artificial Neural Network (ANN)
Genetic Algorithm (GA).



Kennedy Space Center

RT Anomaly Detection



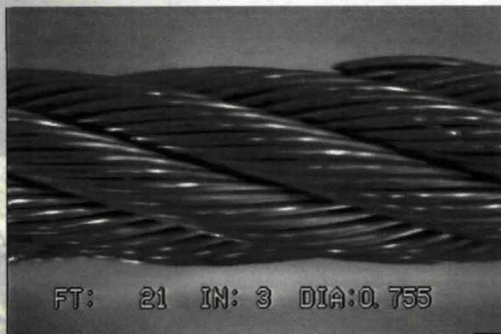
ASRC Aerospace Corp.



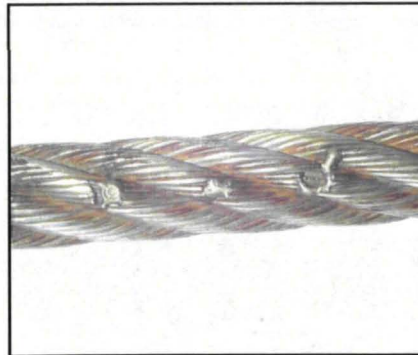
Astronauts training on the emergency egress system.



Anomalies on the basket slidewire



Broken strand.



Molten spots caused by lighting.



RT Anomaly Detection (Cont.)



ASRC Aerospace Corp.

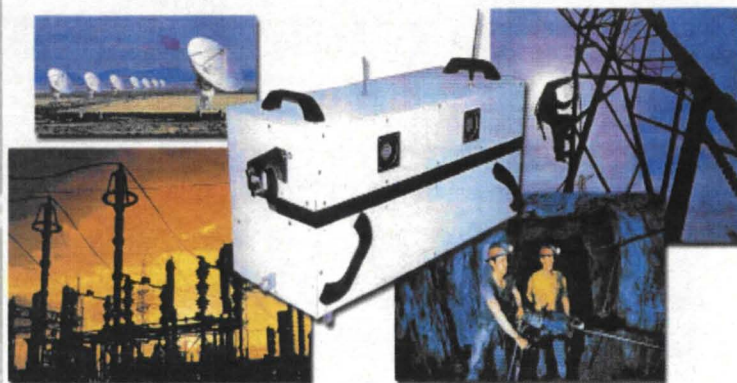
Kennedy Space Center



Cable and Line Inspection Mechanism (CLIM)

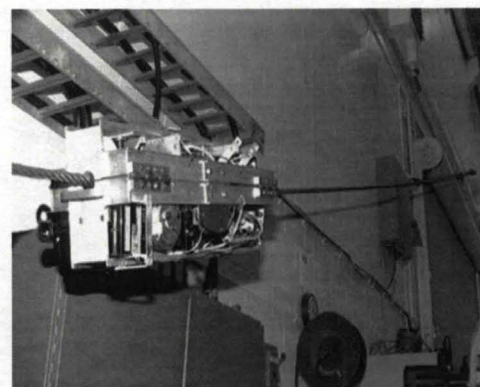
The National Aeronautics and Space Administration (NASA) seeks to transfer the NASA-developed Cable and Line Inspection Mechanism technology to private industry for use in commercial applications. This mechanism was developed at the John F. Kennedy Space Center (KSC) to provide a means for automated inspection of the seven slidewire cables used in the emergency egress system for the Space Shuttle. There are two sets of gantry cables plus an overhead lightning cable that require periodic inspection. These cables are nonferrous stainless steel; therefore, magnetic cable testers are not suitable for such inspections. Prior to this invention, cable inspections required 150 man-hours twice per year, with inspectors being hoisted in baskets to manually inspect the cables by

direct touch and sight. The CLIM technology eliminates the hazardous, manpower-intensive, and time-consuming methods previously required to maintain the emergency egress system at peak performance standards. In addition, CLIM is capable of inspecting the top end of ferrous wire ropes near the attachment point in the cable housing where magnetic cable testers are unable to reach. CLIM has a further application with respect to radio frequency (RF) tower guy-wire inspections. The low-carbon, low-magnetic inductance of the stainless-steel guy-wire cables, combined with added RF radiation interference from the tower, yields magnetic cable testers ineffective. Therefore, CLIM's ability to conduct a 360-degree view of the cable without incurring RF radiation interference is significant.



National Aeronautics and Space Administration
John F. Kennedy Space Center, FL

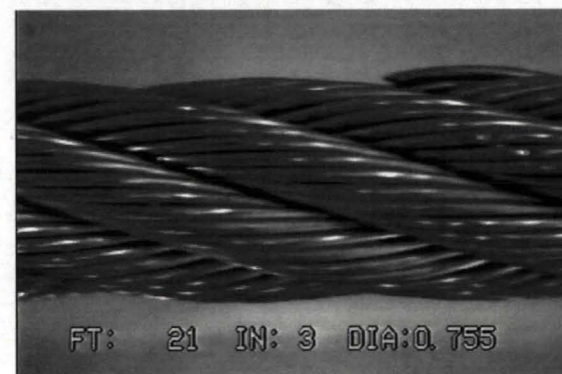
Cable & Line Inspection Mechanism (CLIM) built by NASA.



CLIM at the lab.



CLIM at the Shuttle Pad



Slidewire image acquired by CLIM



Kennedy Space Center

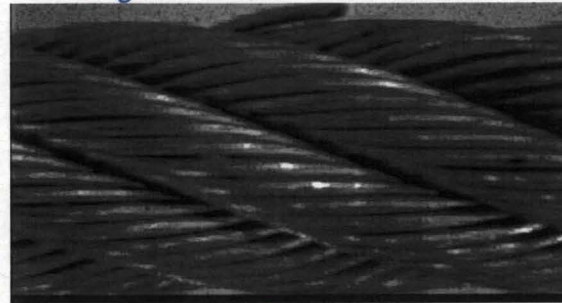
RT Anomaly Detection (Cont.)



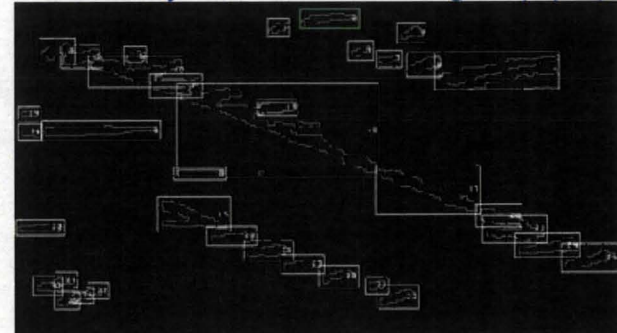
ASRC Aerospace Corp.



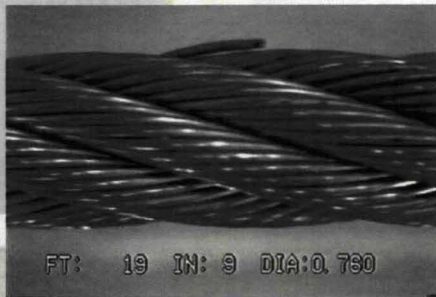
Background Extraction + FRED



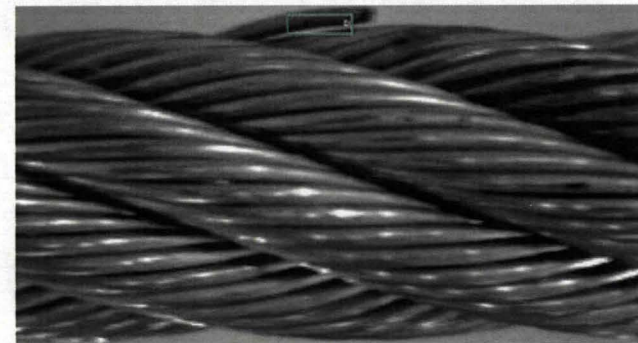
Blob analysis via ANN-GA engine (input)



Original



Binarization via FRAT



Anomaly Detection via ANN-GA engine (output)

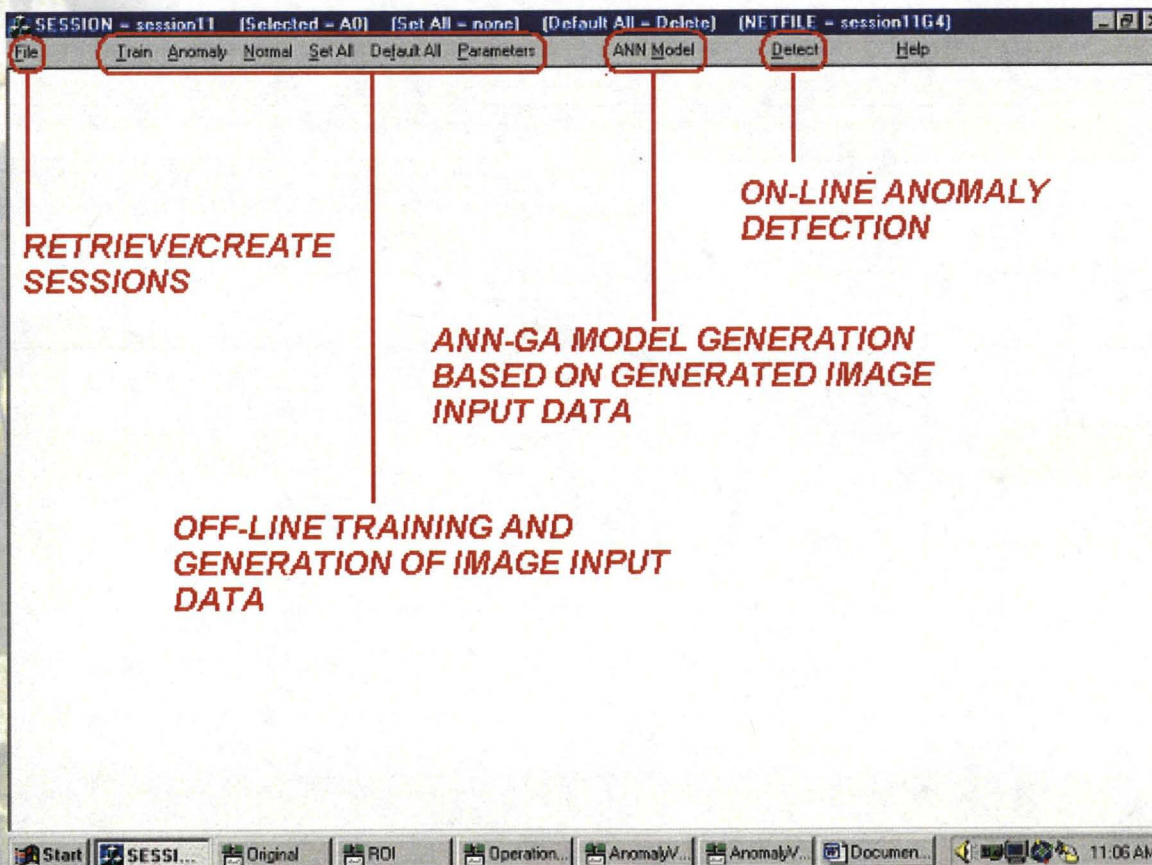


Kennedy Space Center

RT Anomaly Detection (Cont.)



ASRC Aerospace Corp.



*End-user front
end built via
MFC.*

Main Menu

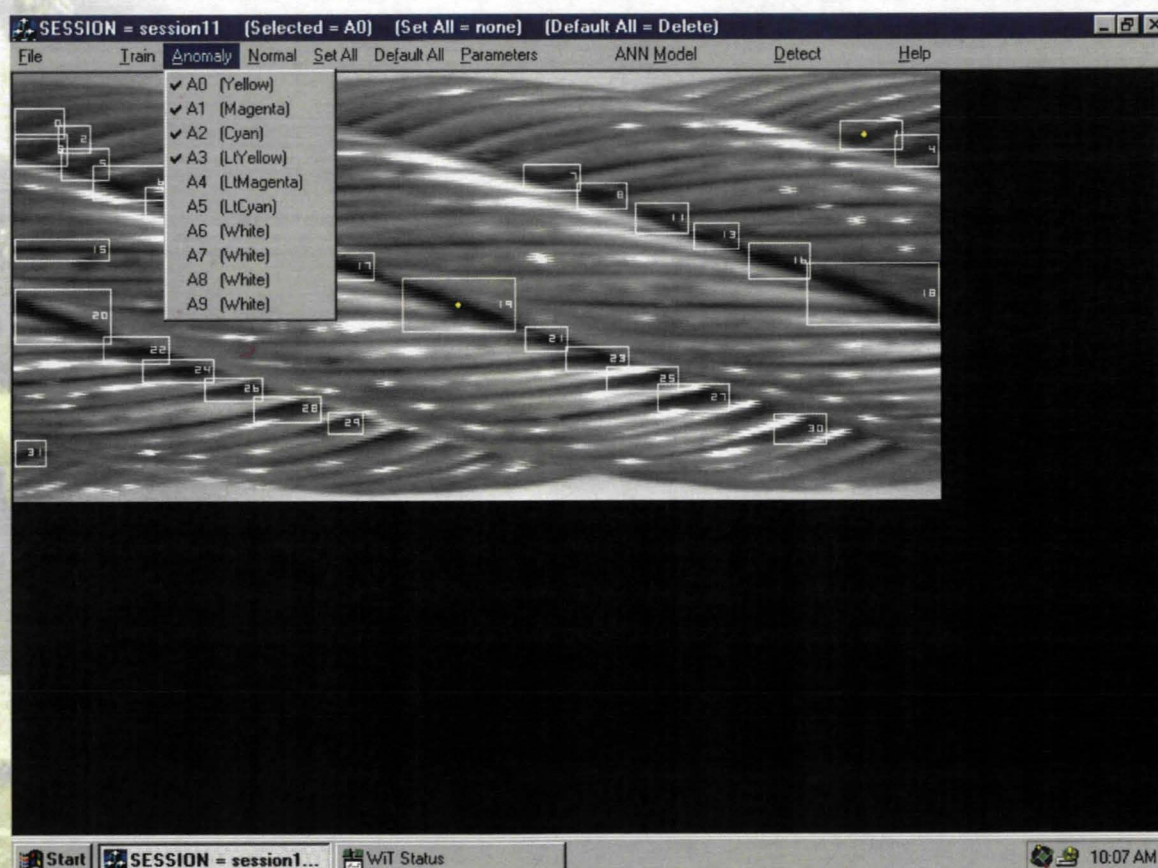


RT Anomaly Detection (Cont.)

Kennedy Space Center



ASRC Aerospace Corp.



*End-user front
end built via
MFC.*

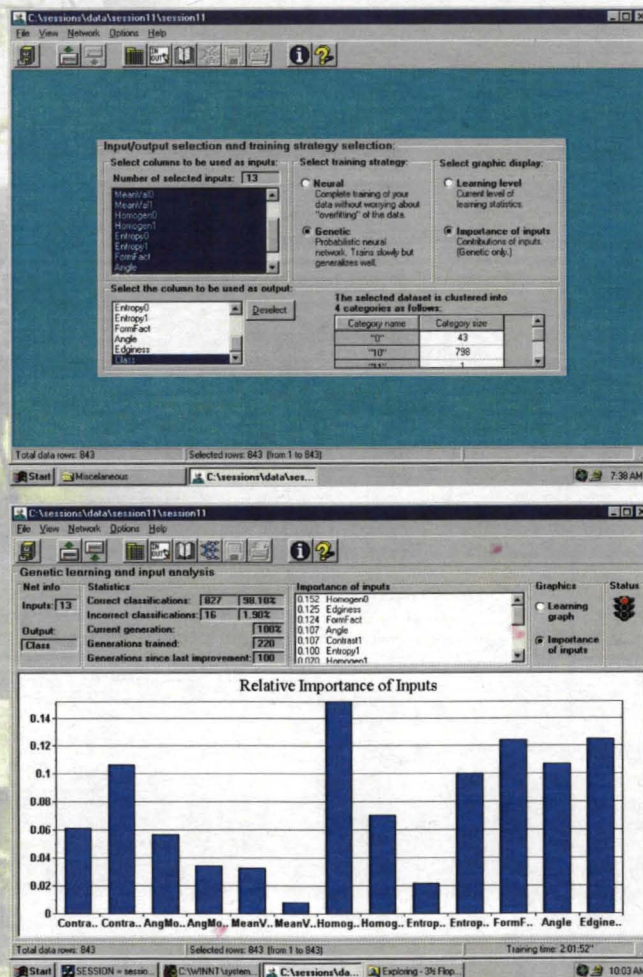
Training Stage.

RT Anomaly Detection (Cont.)

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NeuroShell Classifier - Trained Network Information

Network filename: C:\sessions\data\session11\session11G3.net

The network was trained on:

Filename: C:\sessions\data\session11\session11.dat
Total data rows: 798
Training rows: 798
Start row: 1
End row: 798

Results of training session:

Training time: 1:20:16"
Generations trained: 178
Correct classifications: 98.87% (789 of 798)
Incorrect classifications: 1.13% (9 of 798)
Performance by category:
"0" 90.48% (38 of 42)
"10" 99.34% (751 of 756)

Network structure:

Training strategy: Genetic
Output name: "Class"
Number of inputs: 13
List of inputs and their relative importance:
"Contrast0" 0.006
"Contrast1" 0.163
"AngMom20" 0.074
"AngMom21" 0.018
"MeanVal0" 0.018
"MeanVal1" 0.074
"Homogen0" 0.095
"Homogen1" 0.045
"Entropy0" 0.184
"Entropy1" 0.01
"FormFact" 0.094
"Angle" 0.115
"Edginess" 0.106

*Development of
classification
model via ANN &
GA (NeuroShell)*

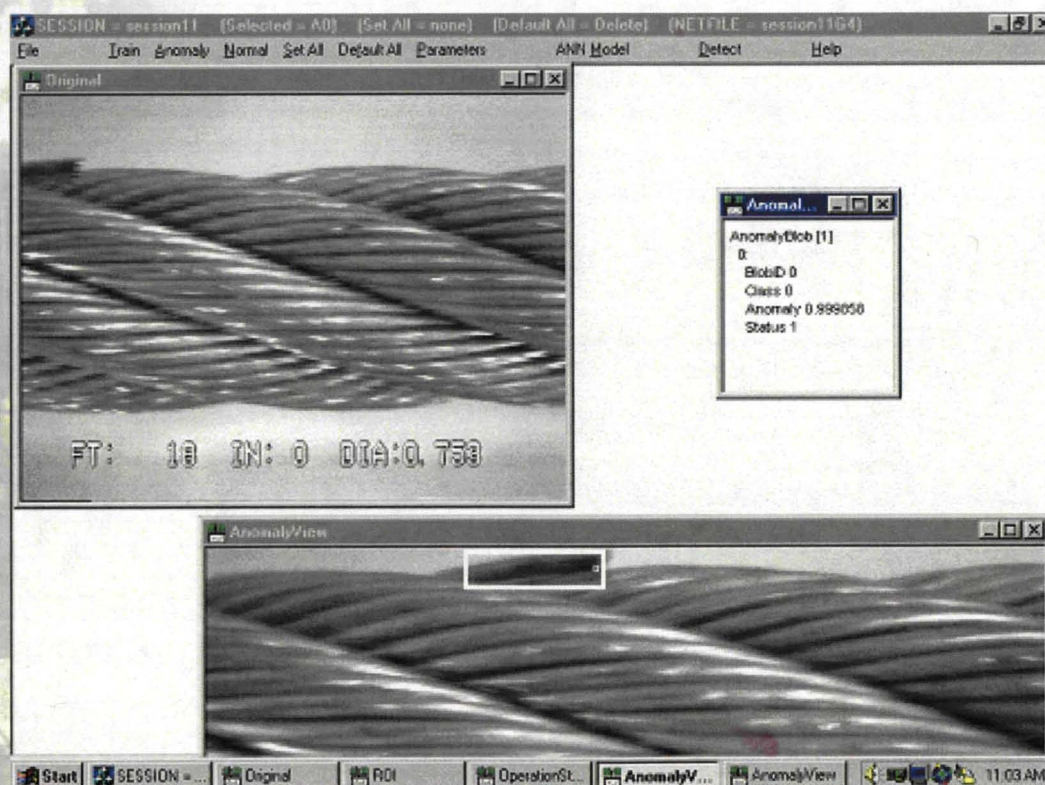


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RT Anomaly Detection (Cont.)



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*Anomaly Detected
& displayed in RT.*

Firing stage

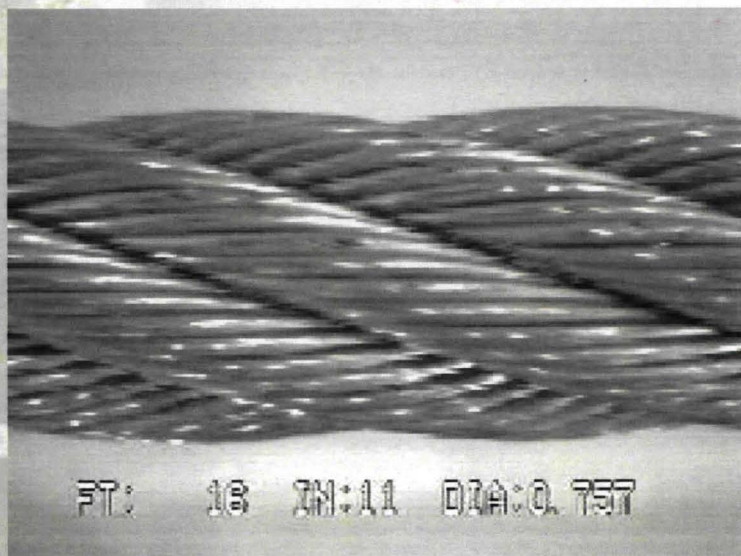


Kennedy Space Center

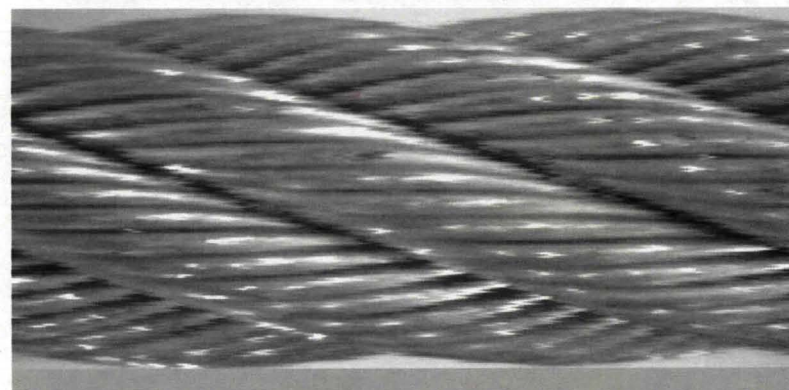
RT Anomaly Detection (Cont.)



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Original image acquired by CLIM



*Automated Region of Interest (ROI)
extraction and anomaly detection.*



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RT Moving FOD Detection



- *Blob Generation (single image).*
Segmentation (Binarization)
- *Blob/FOD Selection and Trajectory Computation*
Logical path analysis (consecutive images).

FRAT



RT Moving FOD Detection (Cont.)



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Kennedy Space Center





Kennedy Space Center

RT Moving FOD Detection (Cont.)



ASRC Aerospace Corp.



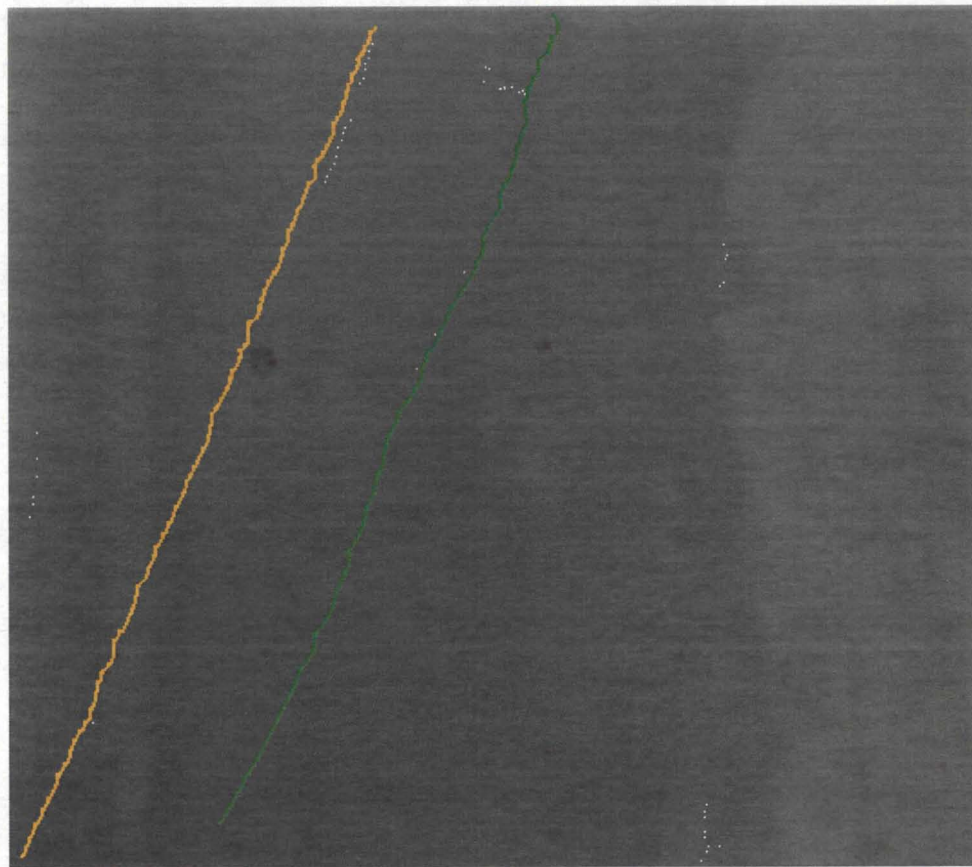


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RT Moving FOD Detection (Cont.)



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Columbia Investigation



Foam Debris

- 2D: Detection & Location.

Segmentation (Binarization)

FRAT

Characterization (center of mass, borders, etc.)

- 3D: Location & Trajectory

Optimal path at three consecutive 3D projections.



Kennedy Space Center

Columbia Investigation



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STS-107 REPORT:

***2D-Detection, 3D-Location & 3D-Velocity Estimation of
Foam Debris Based on Images acquired by E212 & E208
Video Cameras.***



ASRC Aerospace Corp.



Jesus A. Dominguez, ASRC Aerospace Corp.

NASA Kennedy Space Center, June 12, 2003



Columbia Investigation: Foam Debris Detection/Location (Cont.)

Kennedy Space Center



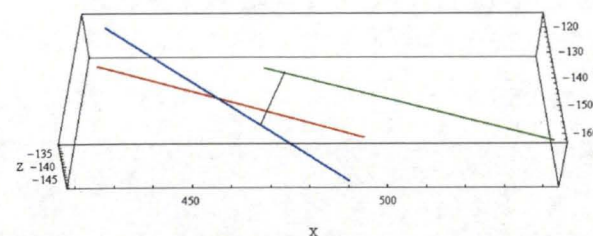
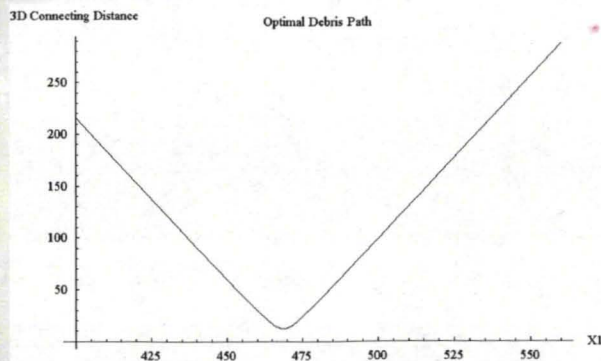
E212 at 21.753 s



ET208 at 21.757 s



E212 at 21.769 s



E212 at 21.753 s

E212 at 21.769 s

ET208 at 21.757 s

Optimized path.



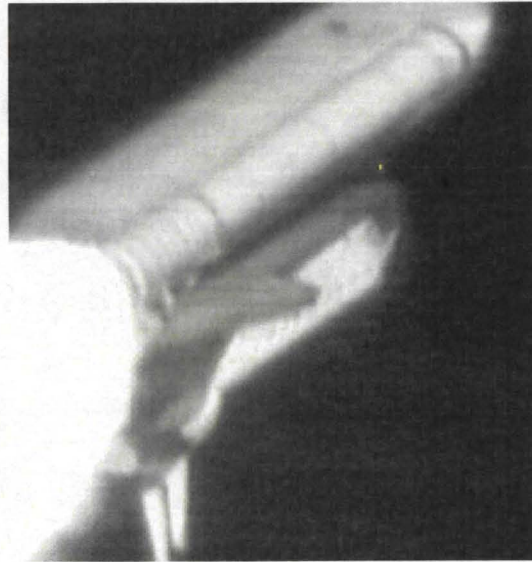
Columbia Investigation: Foam Debris Detection/Location (Cont.)

Kennedy Space Center

ASRC Aerospace Corp.



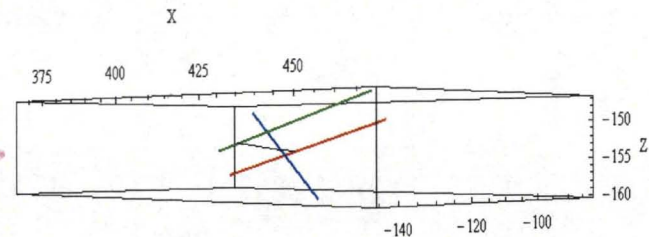
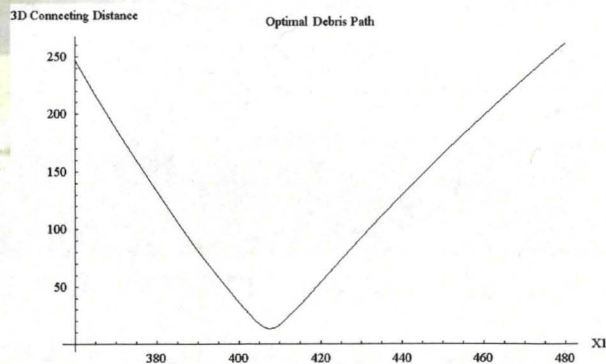
E212 at 21.722 s



ET208 at 21.724 s



E212 at 21.738 s



E212 at 21.722 s **E212 at 21.738 s**
ET208 at 21.724 s **Optimized path.**



Columbia Investigation: Foam Debris Detection/Location (Cont.)

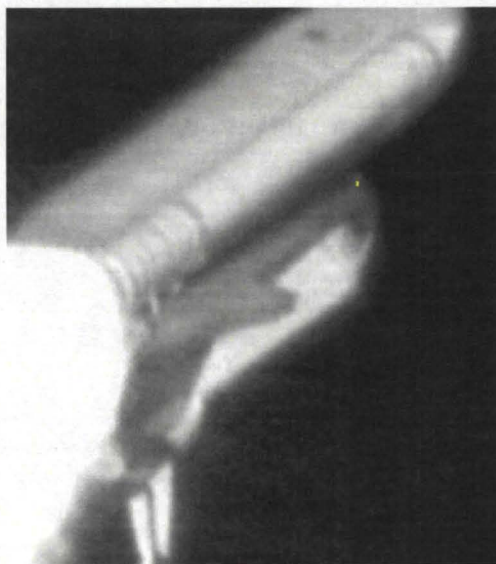
Kennedy Space Center



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E212 at 21.753 s



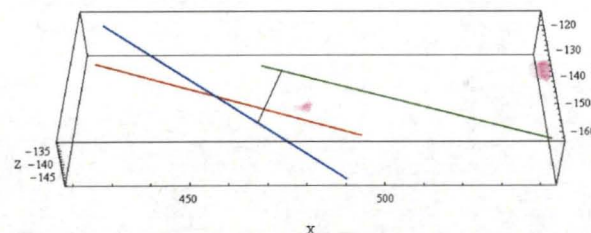
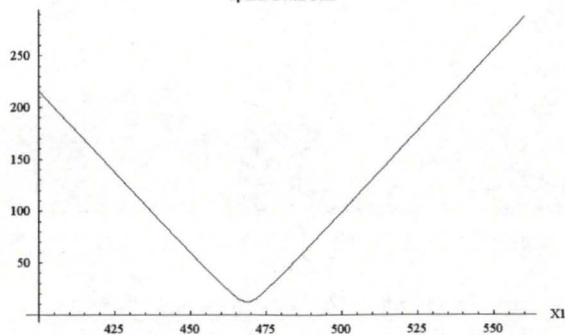
ET208 at 21.757 s



E212 at 21.769 s

3D Connecting Distance

Optimal Debris Path



E212 at 21.753 s

E212 at 21.769 s

ET208 at 21.757 s

Optimized path.



Columbia Investigation: Foam Debris Detection/Location (Cont.)

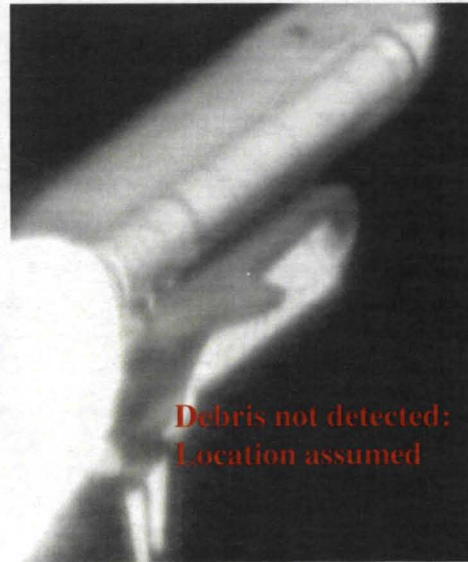
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— E212 at 21.784 s

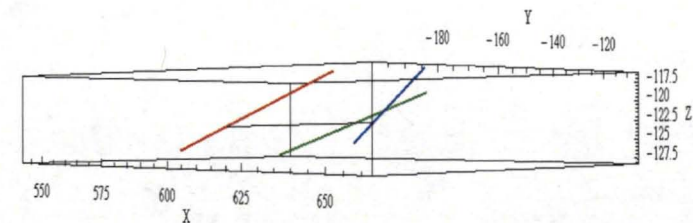
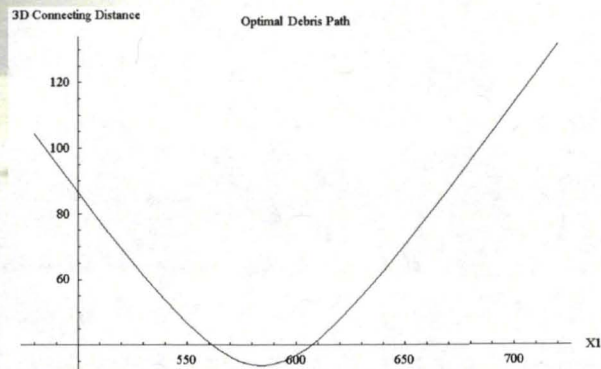


Debris not detected:
Location assumed

— ET208 at 21.791 s



— E212 at 21.800 s



— E212 at 21.784 s — E212 at 21.800 s
— ET208 at 21.791 s — Optimized path.



Kennedy Space Center

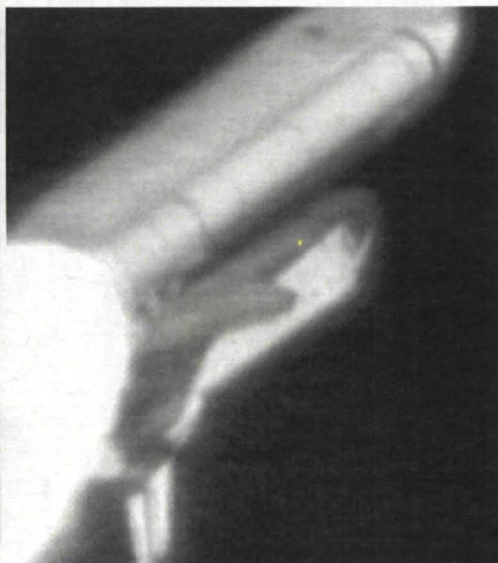
Columbia Investigation: Foam Debris Detection/Location (Cont.)



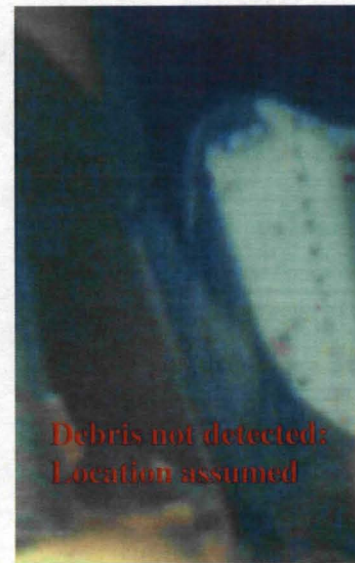
ASRC Aerospace Corp.



E212 at 21.816 s

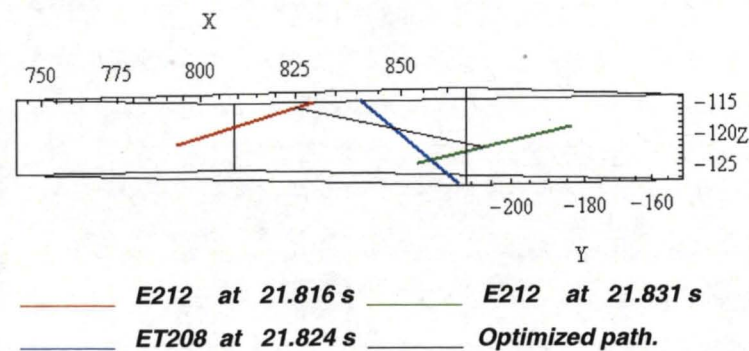
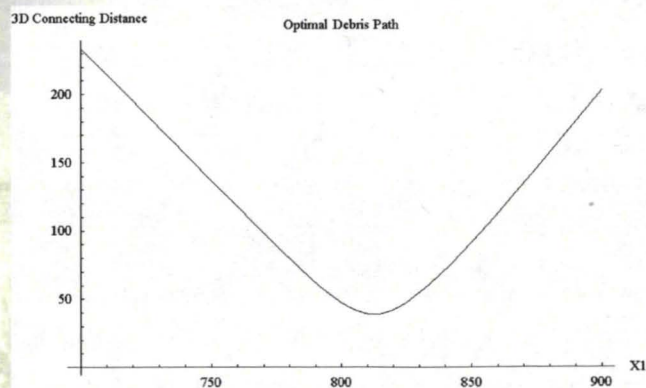


ET208 at 21.824 s



E212 at 21.831 s

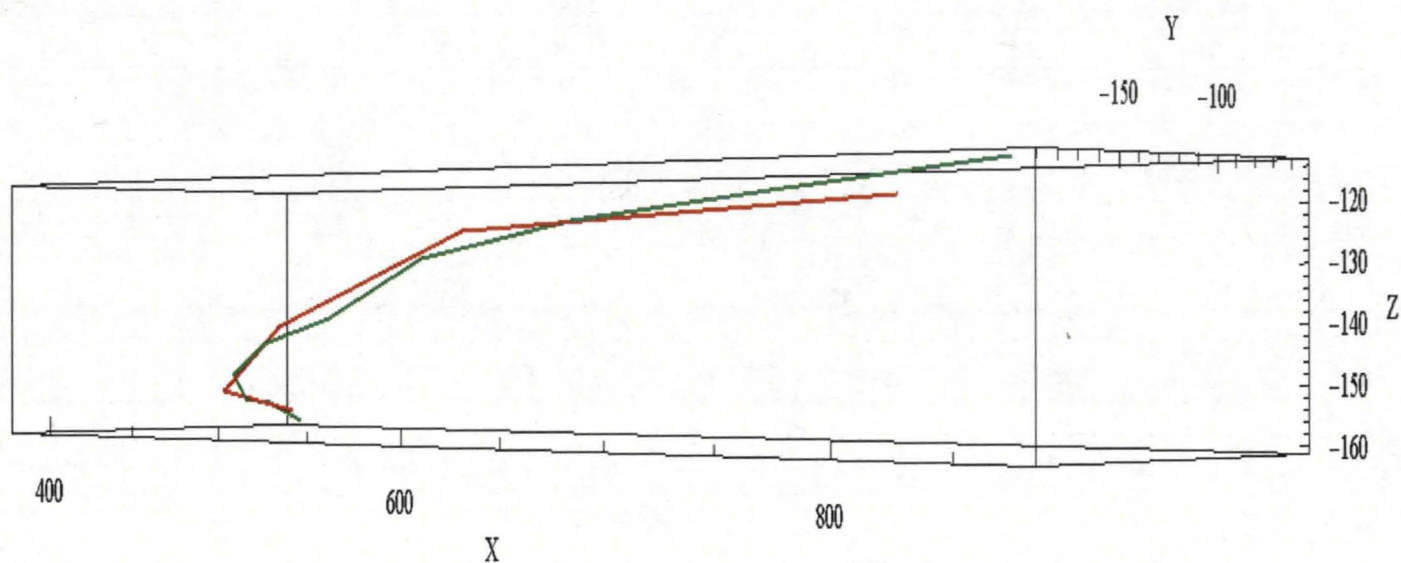
Debris not detected:
Location assumed





Kennedy Space Center

Columbia Investigation: Foam Debris Trajectory



— **Current Work** — **Lane-Nelson work via LighWave3D**

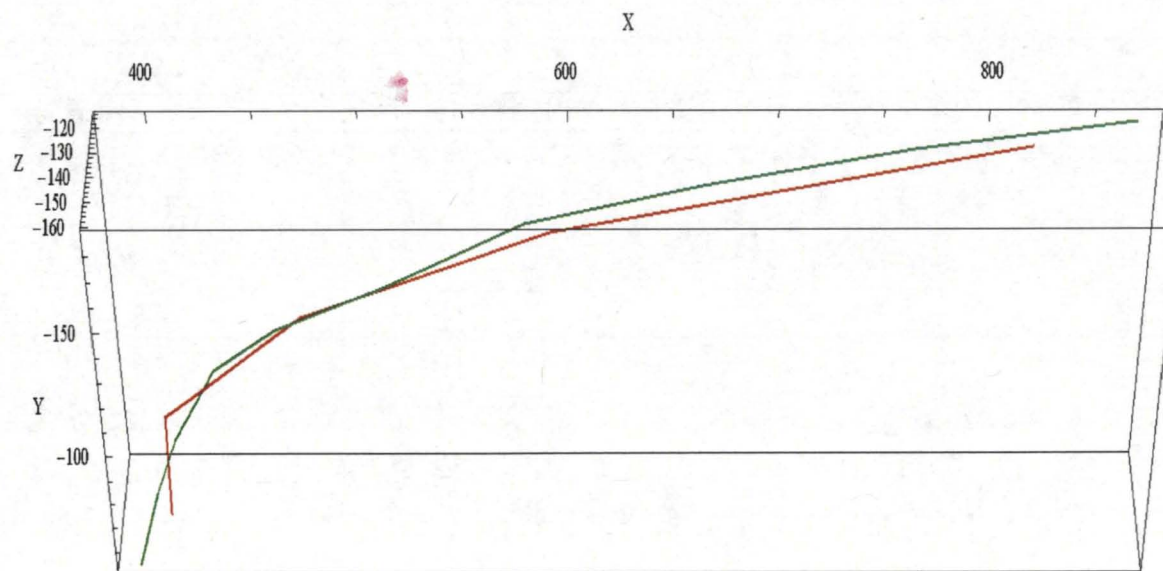


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Columbia Investigation: Foam Debris Trajectory

Kennedy Space Center



— Current Work — Lane-Nelson work via LighWave3D

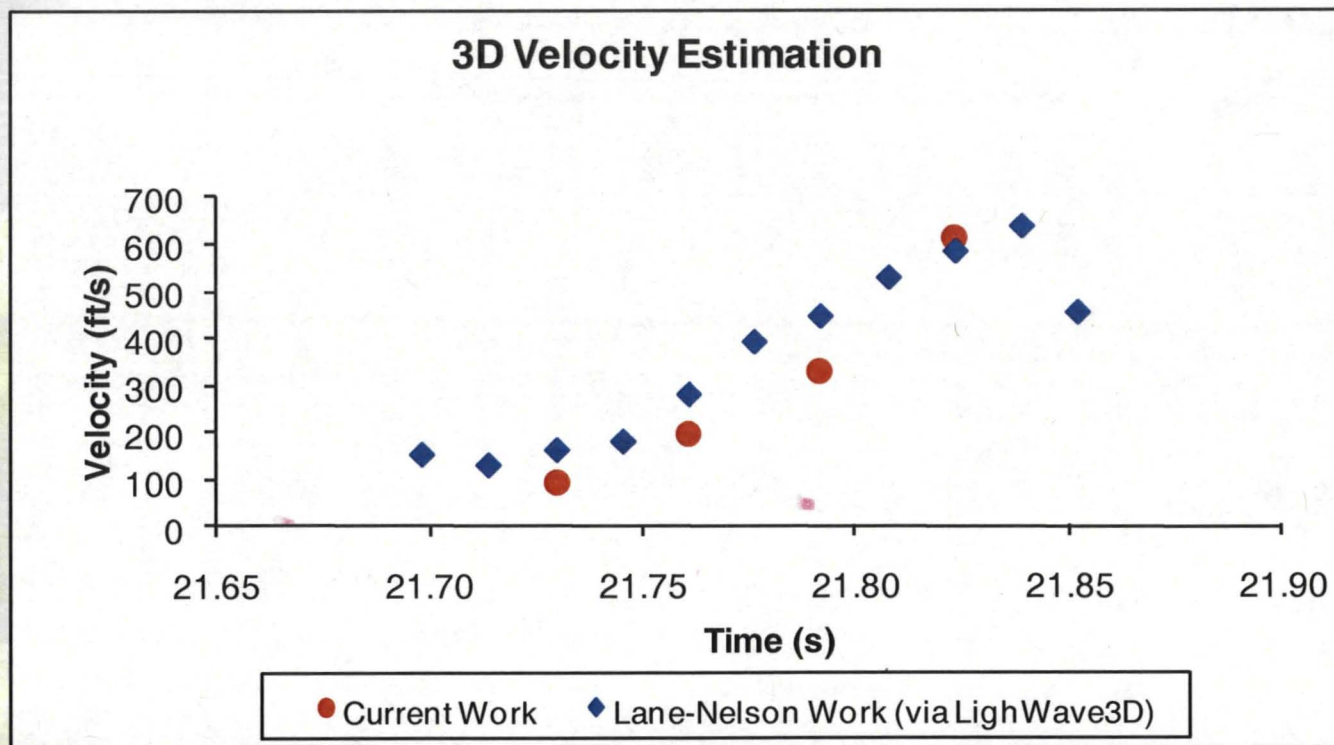


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Columbia Investigation: Foam Debris Velocity



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Proposed Debris Analysis Software System Development at KSC

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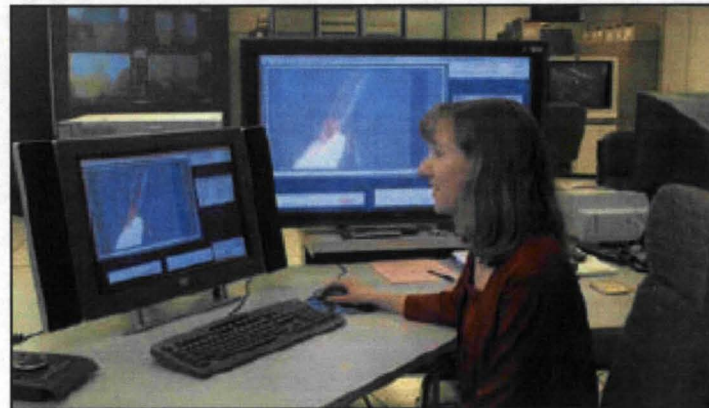


Automated Debris Detection at KSC VAB Launch Analysis Laboratory

sgi®



*Current OS housing FRAT,
FRED, SC-based image
pattern recognition.*



*VAB Launch Analysis Laboratory at
KSC equipped with recently acquired
SGI Reality Center facility with a 7-
foot display, and advanced SGI
TP9500 data management
subsystem.*



ASRC Aerospace Corp.



Kennedy Space Center

Commercialization: Licensing



ASRC Aerospace Corp.



Patent



NASA KSC

Technology Marketing



*Research Triangle Institute (RTI)
Center for Technology Applications
PO Box 12194, 3040 Cornwallis
Research Triangle Park, NC 27709*

NASA Technology Applications Team:

Kirsten Rieth

Phone: (919) 967-4991

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Email: krieth@rti.org

John Geikler

Phone: (919) 941-8372

Fax: (919) 941-8399

Email: johng@thesolutioncenter.com



Commercialization (Cont.)

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<http://nasa.rti.org/ksc/imaging>

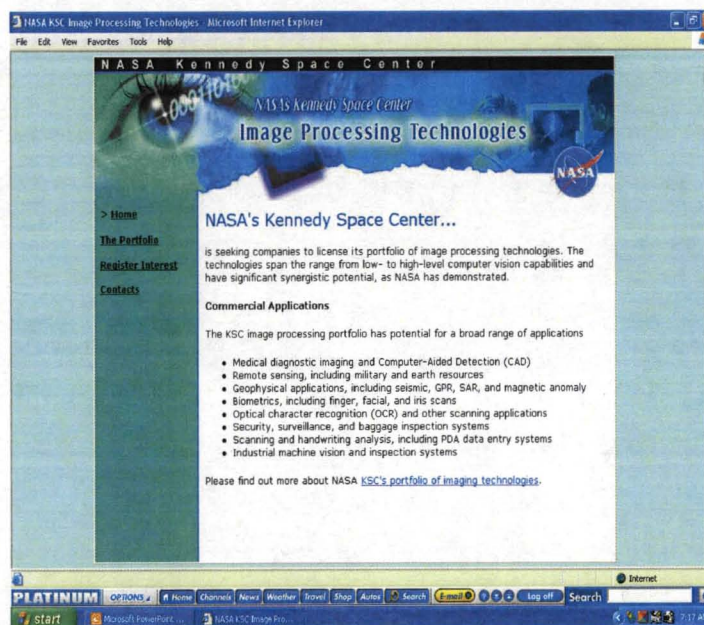


Figure 8

Commercialization (Cont.)

Kennedy Space Center



Technology Opportunities

IMAGE PROCESSING TECHNOLOGY

Binarization of Noisy Images A Fuzzy Reasoning Method



NASA's Kennedy Space Center (KSC) is seeking companies to license its fuzzy reasoning adaptive thresholding (FRAT) system. Used for binarization of gray scale images, this technology is faster and more reliable than current high reliability methods and is especially effective in noisy environments.

Benefits

- Superior performance in noisy, cluttered, or textured images
- More reliable and significantly faster than current fuzzy reasoning approaches
- More reliable than nonfuzzy reasoning approaches and comparable in speed
- Fully developed and proven, effective in a critical NASA system

Commercial Applications

Currently used to analyze launch debris and a crucial part of NASA's investigation into the Space Shuttle Columbia tragedy, FRAT has numerous potential commercial applications, including:

- Medical diagnostic imaging and Computer-Aided Detection (CAD) systems
- Remote sensing, including military and earth resources
- Geophysical applications, including seismic, GPR, SAR, and magnetic anomaly
- Biometrics, including finger, facial, and iris scans
- Optical character recognition (OCR) and other scanning applications
- Security, surveillance, and baggage inspection systems
- Industrial machine vision and inspection systems



Technology

NASA's fuzzy reasoning adaptive thresholding (FRAT) system is ideal for binarizing noisy, cluttered, or textured gray-scale images. Using a faster computational technique that improves on previous fuzzy entropy thresholding, FRAT is faster and more reliable than other current, highly reliable methods.

FRAT defines an image as an array of fuzzy singletons, corresponding to image pixels. With two classes, background and foreground, the membership function is built based on the average gray level of each class, which is computed using the gray-level histogram as average weight factor.

By using an unrestricted range and a straightforward triangular-type membership function, FRAT takes advantage of a simple image function as the basis for its entropy measure. The entropy measure is then used as a cost function for the selection of the optimal image threshold.

FRAT is part of a critical NASA system used to identify and track foreign object debris (FOD) during Space Shuttle launches. FRAT is also a key analysis tool used in the current investigation into the Space Shuttle Columbia tragedy.

FRAT features include:

- Exploitation of image pixel value histogram to avoid dealing with individual pixels
- Use of entropy measure as the criterion for selection of optimal threshold value
- Improvement on membership function to achieve more reliable and faster results

Commercial Opportunities

NASA is seeking companies to license this technology under its technology commercialization program, which seeks to stimulate commercial use of NASA-developed technologies. This technology is currently copyright protected, and a patent application is in process.

For More Information

If you would like more information about this technology or NASA's technology transfer program, please contact:

Karen Skott NASA Technology Applications Team 915.941.4891 915.941.6271 kskott@nasa.gov	John Gaskin NASA Technology Applications Team 915.941.8377 915.941.8395 jgaskin@nasa.gov
---	--



FRAT OCR Potential (Textured)

Then, just a little south, you'll likely of interactive entry in Ch...

Original: 8-bit Image

256 x 256

Then, just a little south, you'll likely of interactive entry in Ch...

Class: 8-bit Image

256 x 256

Then, just a little south, you'll likely of interactive entry in Ch...

Class: 8-bit Image

256 x 256

Then, just a little south, you'll likely of interactive entry in Ch...

NASA's FRAT Method

Class: 8-bit Image

256 x 256

Catalog

Figure 9

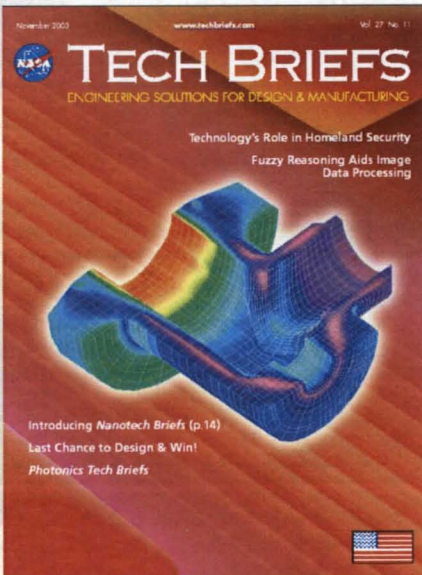


Commercialization (Cont.)

Kennedy Space Center



ASRC Aerospace Corp.



© Detecting Edges in Images by Use of Fuzzy Reasoning

Human visual processing is partly imitated in order to harness some of its power.

John F. Kennedy Space Center, Florida

A model of the perceptual coding of digital images to derive edges includes the use of a set of edge detectors that are sensitive to a particular range of orientations. The edge detectors are assumed to be independent and do not necessarily enhance knowledge of any particular orientation. The model is based on the fact that the human visual system is able to detect a wide range of orientations, and that the use of a set of edge detectors is a good approximation of the human visual system. The model is used in the present research to generate a set of edge detectors that are sensitive to a particular range of orientations, and to use these detectors to generate a set of edge detectors that are sensitive to a particular range of orientations. The model is used in the present research to generate a set of edge detectors that are sensitive to a particular range of orientations, and to use these detectors to generate a set of edge detectors that are sensitive to a particular range of orientations.

Original image

Image after Fourier transform

Image after Inverse Fourier transform

Image after Inverse Fourier transform with Gaussian filter

An image of a Compact Disk was provided by a fluffy reasoning wings deflector and by the Patent and Trademark Office.



Data Acquisition

The method has been implemented in a C language computer program. The method was tested by applying the program to an image of a compact disk. As shown in the figure, the method pro-

known better at detecting edges than did computer programs that implemented non-polar edge detectors similar to the known as the Sobel and Prewitt methods. The programs of the present method even detected a dark cross at a spot containing no real edges that the programs of Sobel and Prewitt methods did not detect at all.

This work was done by James A. Dransfield and Steve Rhoads of AARL, Science Corporation for Kennedy Space Center. For further information, access the Technical Support Package (TSP) free on line at www.stbrill.com/tsp under the Physical Sciences category.
KSC-12270

Software for Acquiring Image Data for PIV

John H. Glenn Research Center, Cleveland, Ohio

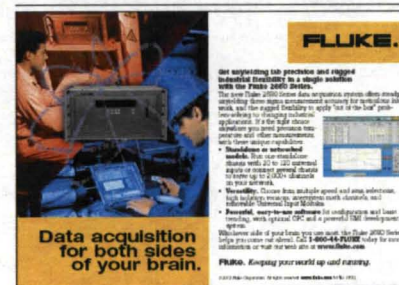
ITV Acquisition (IVACQ) is a con-

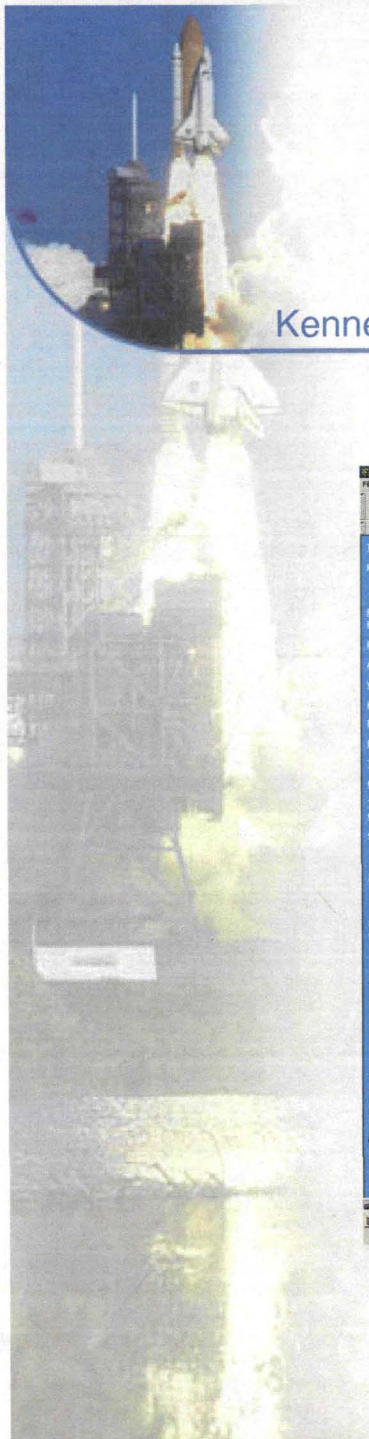
puter program for acquisition of data for particle-image velocimetry (PIV). In the PIV system for which PIVAQ was developed, small particles embedded in a flow are illuminated with a sheet of light from a pulsed laser. The illuminated region is imaged by a charge-coupled device camera that operates in conjunction with a data-acquisition system that includes a frame grabber and a computer data board, both installed in a single computer. The camera operates in 'frame grabble' mode where a pair of images can be obtained closely spaced in time (in the order of microseconds). The same im-

and store the data in the computer's memory. The camera's linear layout reduces the camera's and simplifies the coding of the lines with acquisition of data from the camera. PIVPRO coordinates all of these functions and provides a graphical user interface, through which the user can control the PIV data acquisition system. PIVPRO enables the user to acquire a sequence of single-exposure images, display the images, process the images, and then save the images to the computer hard drive. PIVPRO works in conjunction with the PIVPRO-Prep (as described in ref. 15, NIST, Gaithersburg, MD).

This program was written by Mark Z. Winet of Glenside Research Center, c/o R. M. Channing of the University of Akron, and Steve Kessler of Cornell University. For further information, access the Technical Support Page (TSP) free on line at www.solidlight.com under the Software category.

Inquiries concerning rights for the commercial use of this invention should be addressed to NAXA Glenside Research Center, Commercial Technology Office, Attn: Steve Finer, Mail Stop 438, 21500 Brookfield Road, Cleveland, Ohio 44135. Refer to JPH 27277.



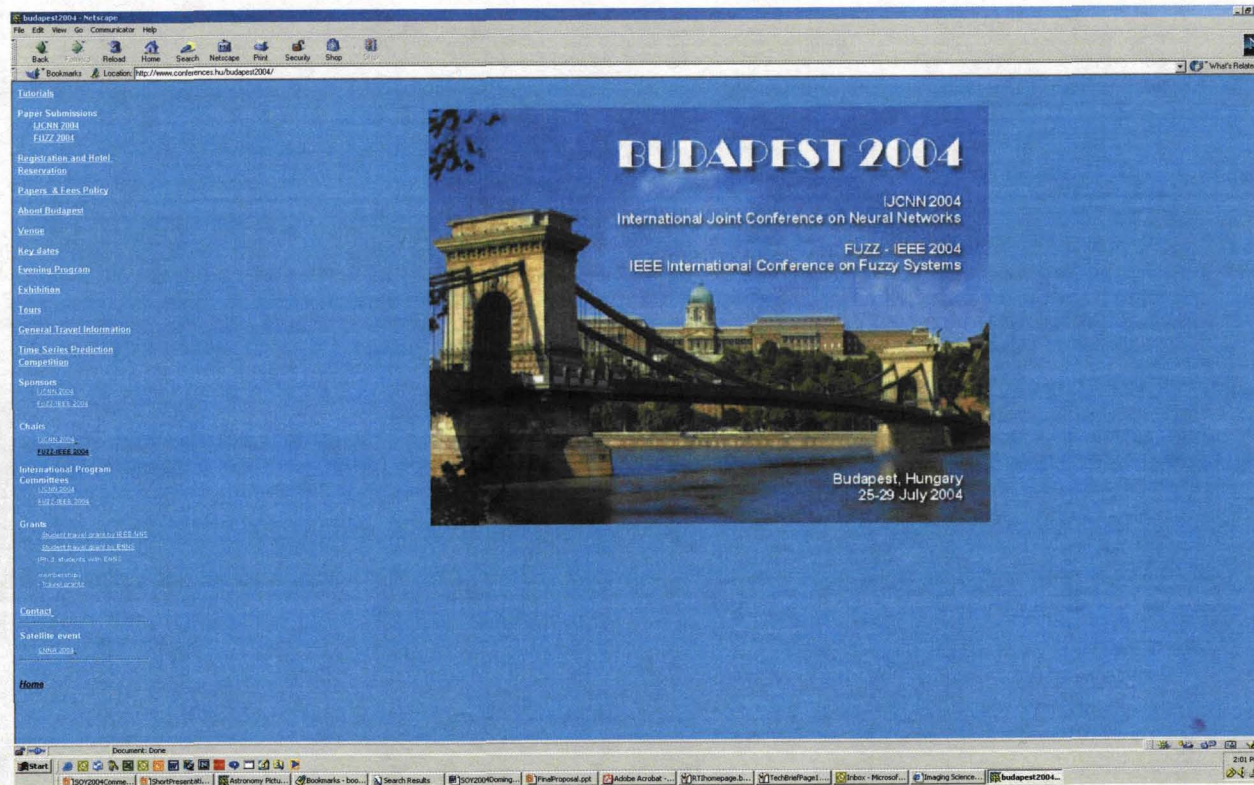


Commercialization (Cont.)

Kennedy Space Center



ASRC Aerospace Corp.



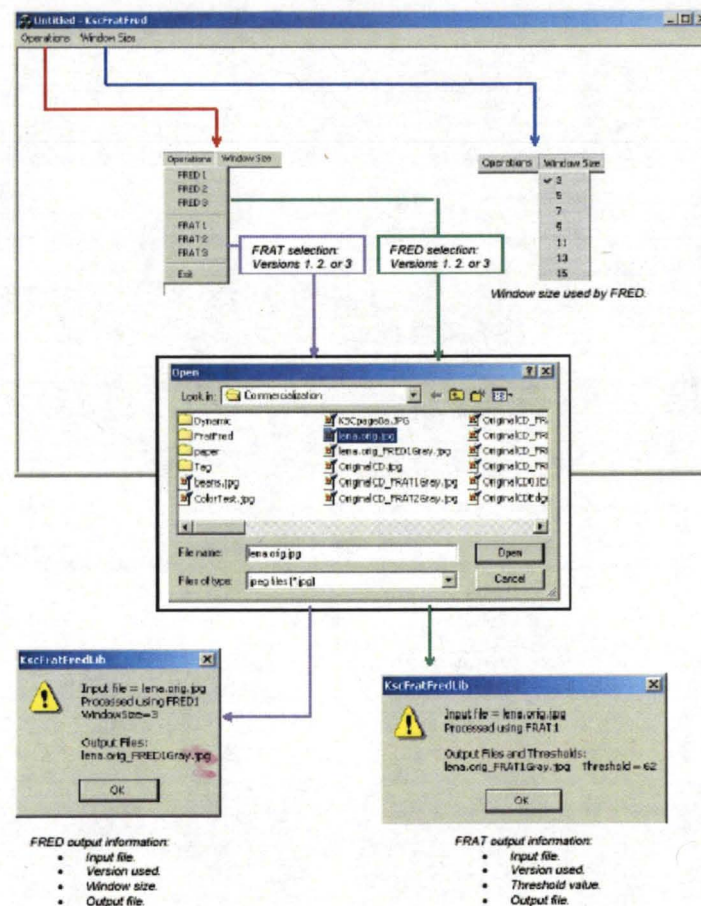
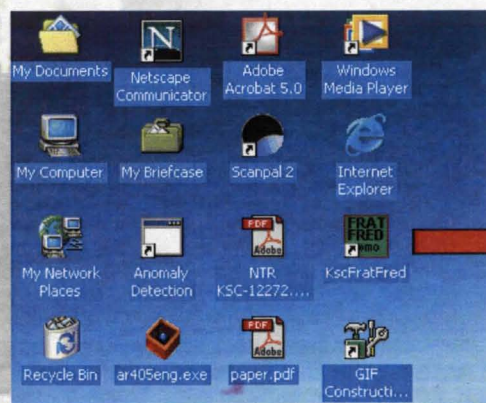


Commercialization (Cont.)

Kennedy Space Center



ASRC Aerospace Corp.





Kennedy Space Center

Commercialization: Status Summary



ASRC Aerospace Corp.



- *Patents already filed by NASA (February 2004).*
- *Marketing and Promotion already in place by RTI.*
- *2 Software Usage Agreements executed.*
- *2 License Agreements executed.*
- *3 License Agreements being executed.*
- *3 License Agreements in negotiation.*



Commercialization: Selected Applications

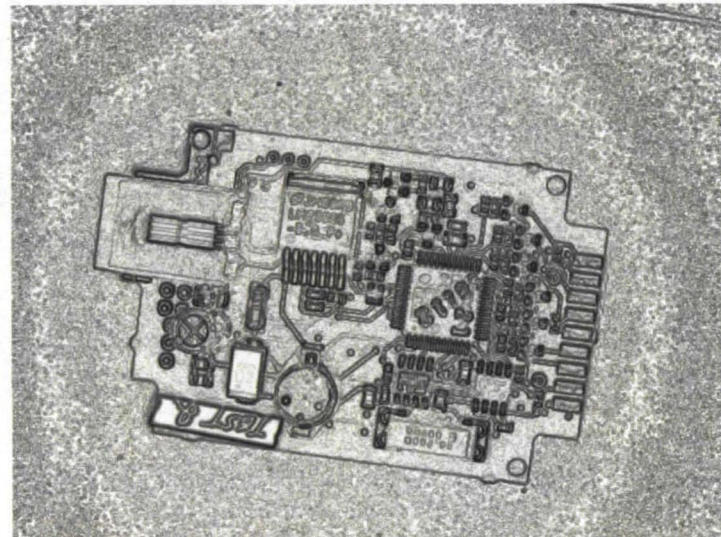
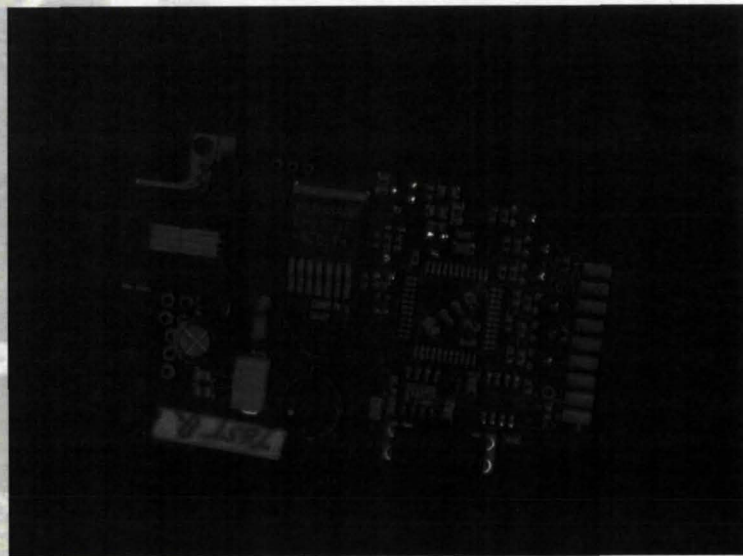
Kennedy Space Center



ASRC Aerospace Corp.



Image enhancement





Commercialization: Selected Applications

Kennedy Space Center



ASRC Aerospace Corp.



이것은 비상사태 방송 체계의
시험 이다.

Original gray-scaled image

이것은 비상사태 방송 체계
시험 이다.

Binarization via FRAT.

이것은 비상사태 방송 체계
시험 이다.

Binarization via Otsu method.

이것은 비상사태 방송
시험 이다.

Binarization via Huang-Wang method.

이것은 비상사태 방송 체계의
시험 이다.

Enhancement prior Binarization
(via FRAT).



Commercialization: Selected Applications

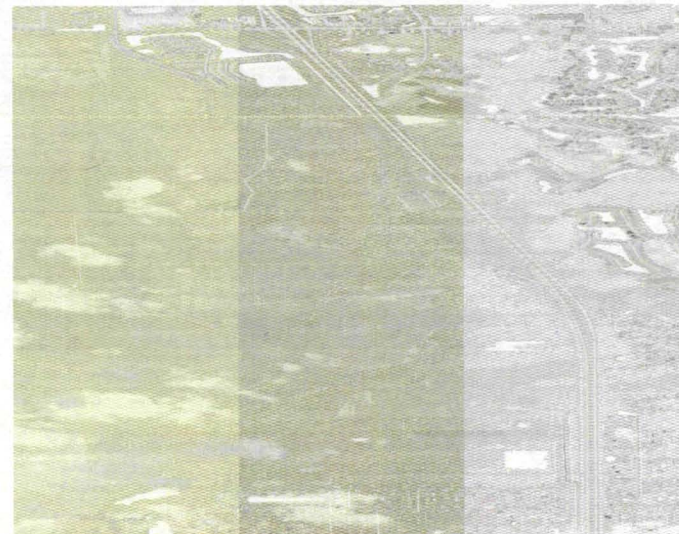
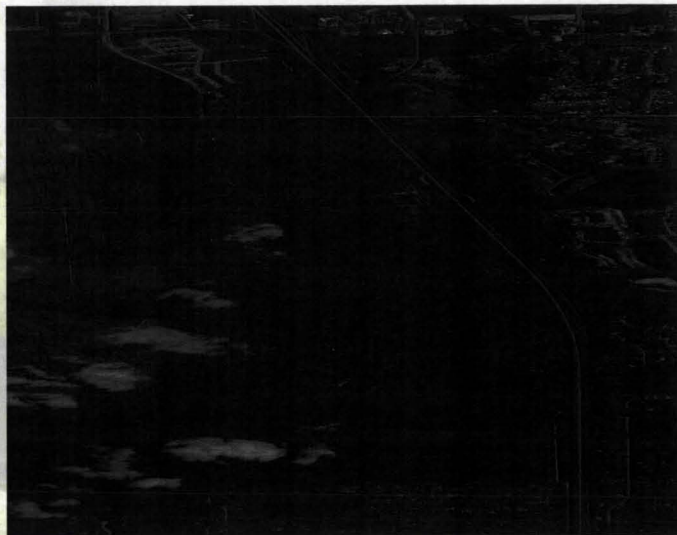
Kennedy Space Center



ASRC Aerospace Corp.



Image enhancement





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Commercialization: Selected Applications

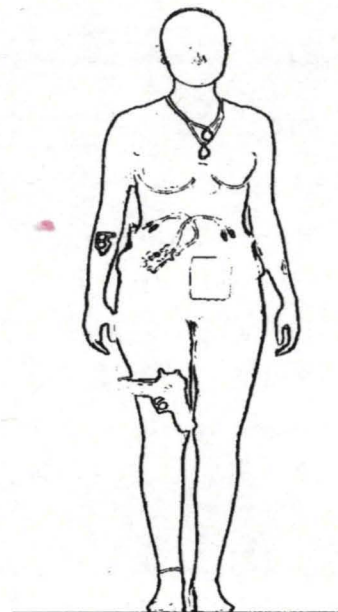
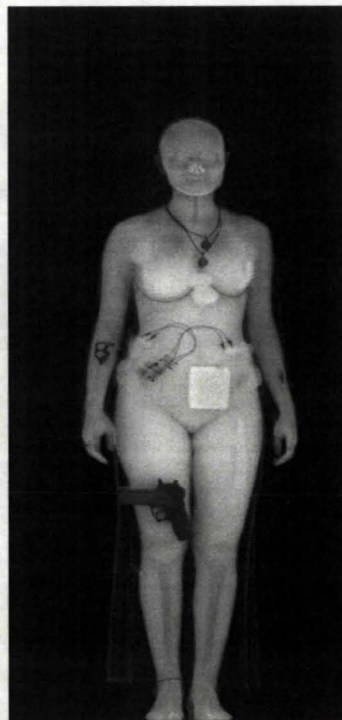


ASRC Aerospace Corp.



AS&E Inc.

Human Screening & Privacy Protection





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Commercialization: Selected Applications

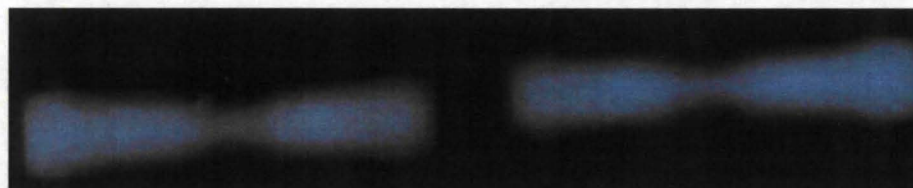


ASRC Aerospace Corp.

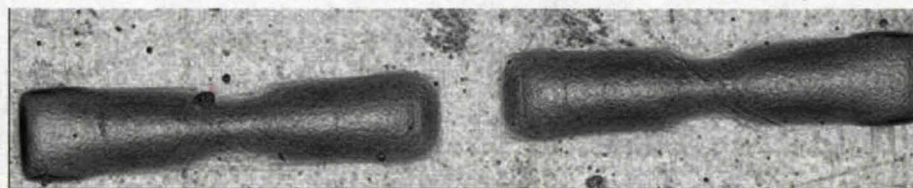


NASA JSC

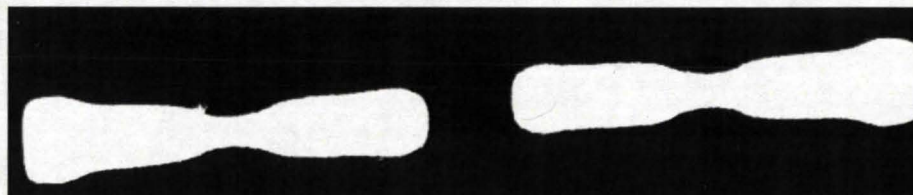
Visual inspection based on x-ray images



*Original x-ray image of
two pyrotechnic valves.*



Enhancement via FRED



Segmentation via FRAT



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Commercialization: Selected Applications

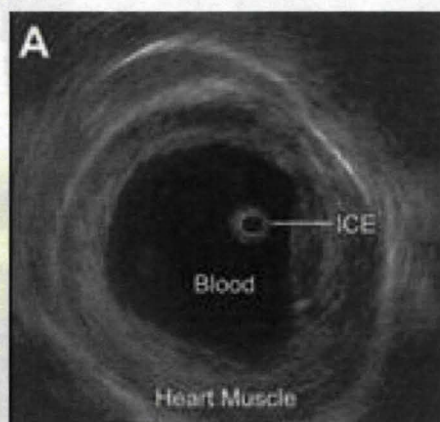


ASRC Aerospace Corp.

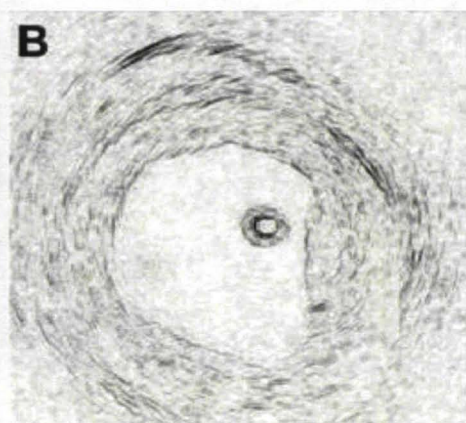


Baylon School of Medicine

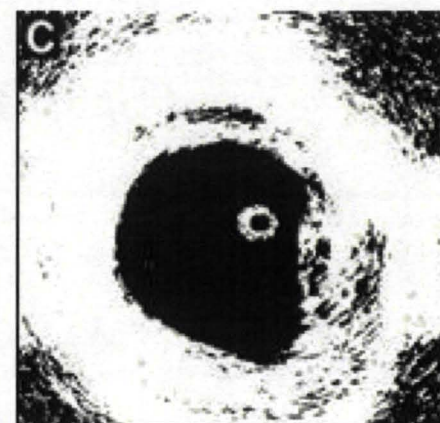
3D heart Visualization



Original image



FRED



FRAT

A. Cross-sectional (tomographic) image of the left ventricular cavity of the dog heart acquired by an intracardiac echocardiography (ICE) catheter. Circle indicates ICE catheter. Dark region indicates blood-filled cavity, which is bounded by the interior surface of the heart (endocardium). **B.** Result of FRED demo when applied to the ICE image depicted in A. **C.** Result of FRAT demo when applied to the ICE image depicted in A.



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Commercialization: Selected Applications

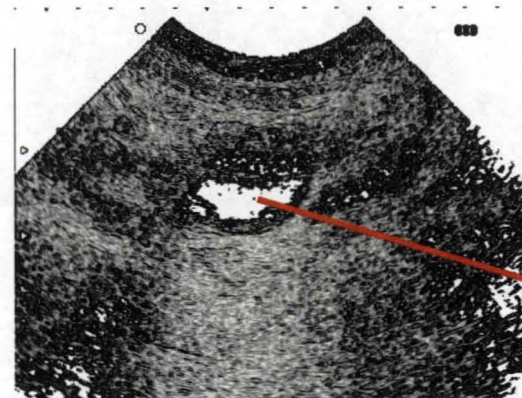


ASRC Aerospace Corp.

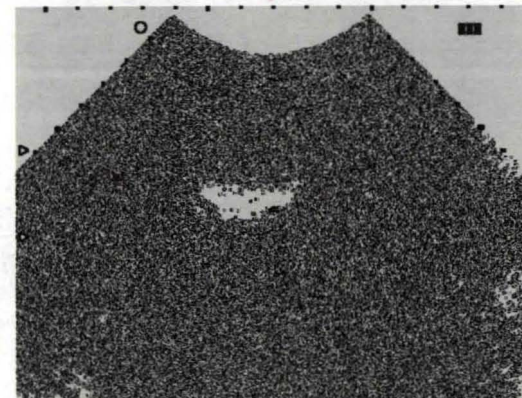


Zeus Technologies, Inc.

Tumor detection on Sonograms



Tumor





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Commercialization: Selected Applications



ASRC Aerospace Corp.



Zeus Technologies, Inc.

X-ray image visualization enhancement

